DEVELOPMENT OF SWITCHABLE PLANAR REFLECTORS FOR BEAM SHAPING REALIZATION

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Sincerely dedicated to my beloved Mother and Father…

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ABSTRACT

This work provides an extensive analysis for the design and performance optimization of planar reflectors within X-band and Ku-band frequency ranges. The objective of this work was to investigate the feasibility of using strategic slot embedded patch element configurations for an efficient reconfigurable reflectarray antenna design. PIN diodes were incorporated with single and multiple slot embedded patch element configurations for the design of beam switchable planar reflectors. Moreover unit cells based on liquid crystal substrates were also designed for comparison between two reconfigurable planar reflector design techniques. 3Dimensional electromagnetic computer models of CST Microwave Studio and Ansoft HFSS were used for the simulations and the results of unit cells were practically verified by waveguide scattering parameter measurements using vector network analyzer. Performance characterization for bandwidth and reflection loss optimization of different slot embedded patch configurations was done based on the scattering parameter measurements. Maximum frequency variation of 2.56GHz with dynamic phase range of 346˚ in X-band was demonstrated by rectangular slots in the centre and circular slots along width configuration while Ku-band measured results demonstrated a maximum frequency variation of 2.54GHz with dynamic phase range of 278˚ for circular slot with gap configuration. The measured scattering parameter results for the PIN diodes based elements designed in X-band frequency range are shown to provide a maximum frequency tunability of 0.55GHz with 238˚ of dynamic phase range in the case of embedded rectangular slots in the centre of patch element. On the other hand liquid crystal based embedded rectangular slots unit cells designed in X-band frequency range are shown to demonstrate comparatively lesser frequency tunability of 0.12GHz with dynamic phase range of 103˚. Although liquid crystal based design is shown to offer good frequency tunability and dynamic phase range, however the loss associated with liquid crystals is one of the limitations of this design. Higher tunable loss factor of 1.91dB was demonstrated by liquid crystal

based design as compared to tunable loss factor of 1.43dB shown by PIN diode based design. The investigations were further extended by carrying out equivalent circuit analysis of PIN diode based and liquid crystal based designs for detailed characterization of reconfigurable planar reflector designs. Equivalent circuit model is demonstrated to offer a very close agreement between the simulated and scattering parameter measured results where a maximum discrepancy of 0.1dB was observed. A comprehensive mathematical model based on Finite Element Method (FEM) was proposed for progressive phase distribution to develop a novel design technique to create a reconfigurable reflectarray antenna based on strategic slot configurations. The developed model permits the positioning of an individual element of the array, required for progressive phase distribution, independent of its geometrical structure. Furthermore the developed algorithm can be used for both centre fed and off-set fed planar reflector designs while incorporating the effect of material properties of conductor and substrate. Three novel robust periodic reflectarray configurations, consisting of 144, 64 and 36 elements respectively were designed and fabricated for far-field radiation pattern measurements. The measured radiation patterns are shown to offer close agreement with the predicted results where switchable array based on PIN diodes confirmed a beam switching of +6˚,0˚and -6˚ while the passive 144, 64 and 36 elements arrays are observed to give maximum 3dB beamwidth of 10.5˚, 11.4˚ and 13.2˚ respectively.

LIST OF PUBLICATIONS AND AWARDS

Following is the list of publications and awards achieved in the result of research presented in this work.

Publications

Book

[1] M. Y. Ismail and M. Inam, *Reflectarray Antennas for Strategic Defense Technology*, UTHM Publisher, 2012 (ISBN 978-967-0468-01-3).

International Refereed Journals

[2] M. Inam, M. Y. Ismail and M. Amin, "*Active Reflectarray Antennas: A Practical Approach for Comparison between PIN Diodes and Liquid Crystal Technology*". Submitted to International Journal of Antennas and Propagation, April 2016.

[3] M. Y. Ismail, M. Inam and F. Mohamed, "*Broadband Reflectarray Antenna based on Highly Conductive Graphene*". Submitted to Microwave and Optical Technology letters, April 2016.

[4] M. Inam and M. Y. Ismail, "*Analysis of Slotted Patch Elements for Phase Agile Reflectarray Antenna Design*". Submitted to ARPN Journal of Engineering and Applied Sciences, April 2016.

[5] M. Inam, M. Y. Ismail and M. Amin, "*X-band Frequency Switchable Reflectarray Antenna Using PIN Diodes*". Submitted to Journal of Applied Research and Technology, December 2015.

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Proceeding papers

International Conferences

[14] M. Y. Ismail and M. Inam, "Equivalent Circuit Modelling of Active Reflectarray Antenna". Accepted for presentation at 18th International Conference on Applications of Wireless and Optical Communications (ICAWOC 2016), Paris, France, June 2016.

[15] M. Y. Ismail and M. Inam, "Liquid Crystal Based Reconfigurable Reflectarray Antenna Design". International Conference on Electrical, Computer, Electronics and Communication Engineering (ICECECE2016), Istanbul, Turkey, January 2016.

[16] M. Y. Ismail and M. Inam, "Development of Switchable Planar Reflectors for Beam Shaping Realization". Fourth International conference on Aerospace and Engineering (ICASE), Islamabad, Pakistan, September, 2015

[17] M. Y. Ismail and M. Inam, "An Efficient Progressive Phase Distribution Consideration of Reflectarray Antennas". The 36th Progress in Electromagnetics Research Symposium (PIERS), Czech Republic, European Union, July, 2015.

[18] M. Y. Ismail and M. Inam, "Design of Liquid Crystal Based Tunable Reflectarray Antenna Using Slot Embedded Patch Element Configurations". XII International Conference on Electrical, Computer, Electronics and Communication Engineering (ICECECE2014), Bali, Indonesia, October 2014.

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Local Conferences

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[29] M. Inam, M. Y. Ismail and A. F. M. Zain, "X-Band Frequency Switchable Planar Reflector using PIN Diodes". Malaysian Technical Universities Conference on Engineering and Technology (MUCET), December 2013, Pahang, Malaysia.

[30] M. Y. Ismail and M. Inam, "Performance Characterization of Passive and Active Reflectarray Antennas". Seminar Hasil Penyelidikan, AKEPT, November 2012, Negeri Sembilan, Malaysia.

Awards

[1] "Best Research Project Presentation at WARAS Postgraduate Colloquium", University Tun Hussein Onn Malaysia (UTHM), Johor, Malaysia, May 2016.

[2] Gold Medal for "Miniaturized Dual Frequency Planar Antenna for Radio Systems", at 2012 Seoul International Invention Fair (SIIF 2012), Dec 2012, COEX Hall, Gangnam Gu Korea.

[3] Special Prize Award by the Korean Invention Association for "Miniaturized Dual Frequency Planar Antenna for Radio Systems", at 2012 Seoul International Invention Fair (SIIF 2012), Dec 2012, COEX Hall, Gangnam Gu Korea.

[4] Gold Medal for "Dual Frequency Flat Reflector for Mobile Communication Systems", 23rd International Invention, Innovation & Technology Exhibition (ITEX 2012), May 2012, Kuala Lumpur, Malaysia.

[5] Gold Medal for "Miniaturized Dual Frequency Planar Array", 11th Malaysia Technology Expo (MTE 2012), The Invention and Innovation Awards, February 2012, Kuala Lumpur, Malaysia.

[6] Special Diamond Medal Award for the category "International Invention of the year" for the invention "Multi-Function Tunable Broadband Flat Antenna", British Invention Show (BIS 2011), Old Spitalfields, London, United Kingdom, October 2011.

[7] Gold Medal for "Multi-Function Tunable Broadband Flat Antenna", British Invention Show (BIS 2011), Old Spitalfields, London, United Kingdom, October 2011.

[8] Gold Medal for "Progressive Phase Distribution Analysis of Reflectarray Antennas", 2011 Research and Innovation Competition (R&I compete 2011), November 2011 UTHM, Johor, Malaysia.

Patents of Research Products

M. Y. Ismail, M. Inam and N. H. Sulaiman, "Miniaturized Dual Frequency Planar Array". PI 2012700925 (Patent Pending).

CONTENTS

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